Liquid Accelerated Cold Spray

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Phase II SBIR Contract # W911QX-11-C-0002

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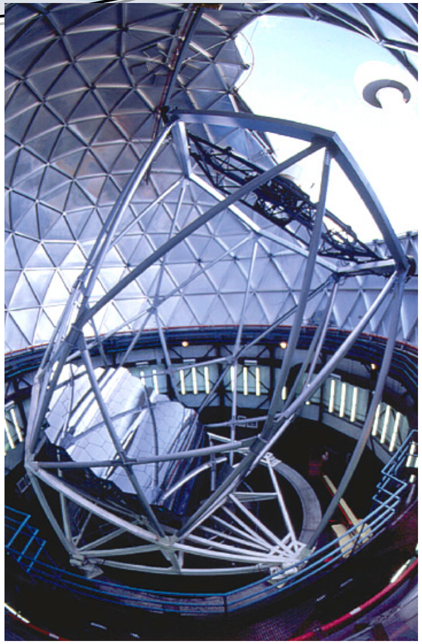
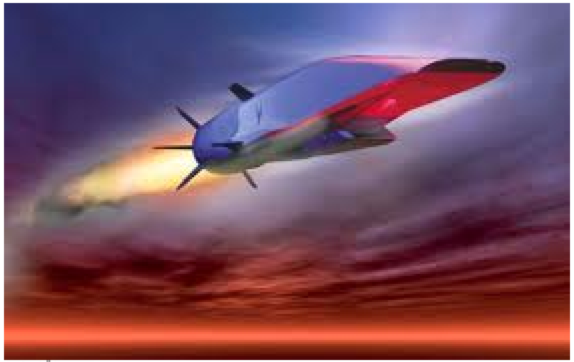
Presentation Summary

- Introduction to Liquid Accelerated Cold Spray
- Phase I SBIR Summary
- Phase II SBIR Objectives
  - Target Applications
- Phase II Work Plan
  - Identify fluid
  - Measure particle velocity
  - Coat coupons and characterize
  - Design of complete system
  - Demonstrate repair process
- Summary

About Ormond

- Ormond engineers have been developing waterjet technology for 20+ years
- Peening, Milling, precision cutting, coating removal, machining ceramics
- Developed and implemented waterjet processes for aerospace, nuclear, oil field, food processing, automotive
- Customers include DoD, NASA, Pratt and Whitney, Sikorsky, Boeing, Rolls-Royce, Baker, Bell, Avure, Sandvik, etc.





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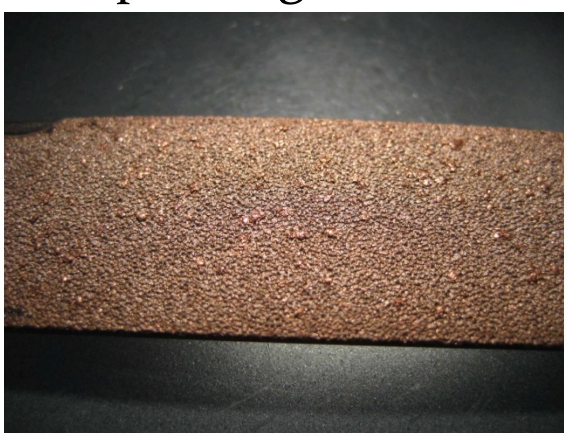
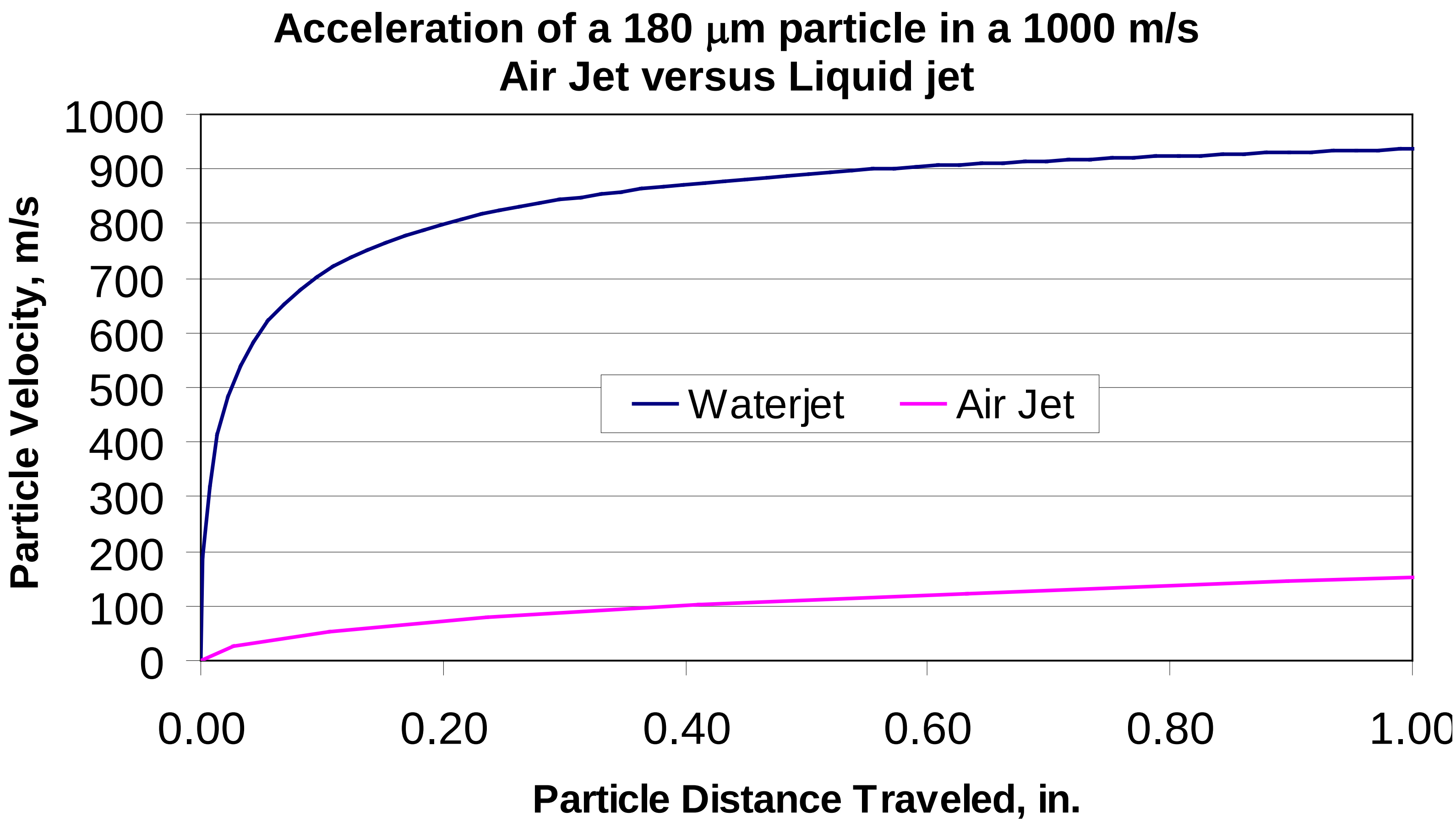
What is Liquid Cold Spray?

- Liquid accelerated cold spray uses high pressure liquid jets to accelerate ductile powders to high velocities so they can form coatings and build-up parts
- Commercially available pumps and robots can be modified to accomplish cold spray.
- Patent pending



Why Liquid not Gas?



Liquids are much more effective at accelerating particles because they are typically 1,000 times denser than gas. Larger, denser particles can be accelerated to higher velocities.

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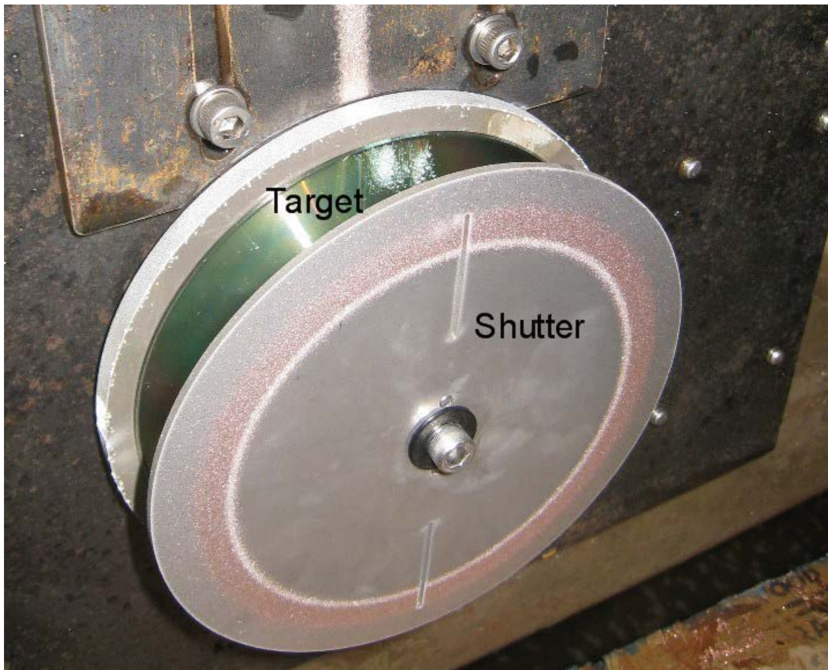
Summary of Phase I

- Measured particle velocity with spinning disks



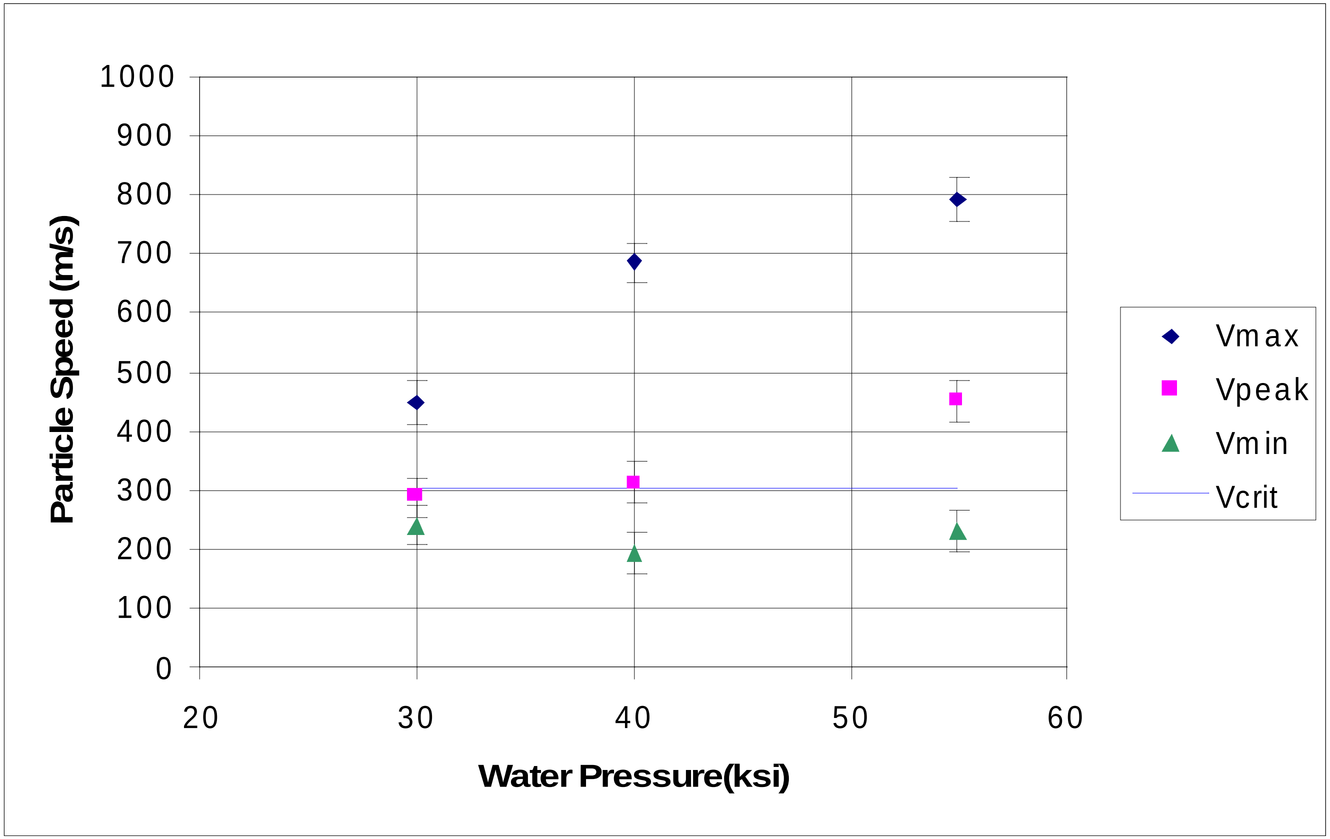
Test Parameters

- Parameters
  - Particle types:
    - AcuPowder #46 Copper, 300 micron average size
    - AcuPowder #61A Copper, annealed, 150 micron average size
    - AcuPowder #151 Copper, 50 micron average size
  - Water pressure: 30, 40, 55, 90 ksi
  - Particle flow rate: 6, 12, 18, 24% of water flow by mass (0.08-1.4 lb/min)
  - Standoff distance: 4, 12, 18 inches
  - Jewel diameter: 0.006, 0.010, 0.014 inch
  - Mixing tube diameter: 0.032, 0.040, 0.056, 0.096 inches
  - Mixing tube length: 4, 7 inches

Parameters required

- 1.Water pressure: >50,000 psi
- 2.Jewel size: >.007 inches for tested mixing tube size
- 3.Mixing tube diameter: <0.08 inches for given jewel size
- 4.Particle flow rate <18% mass flow of water
- 5.Mixing tube length: 7 inches
- 6.Standoff distance: <16 inches
- 7.Particle size: no dependence for size range tested

Velocity versus Jet Pressure



Particles 300 micron copper

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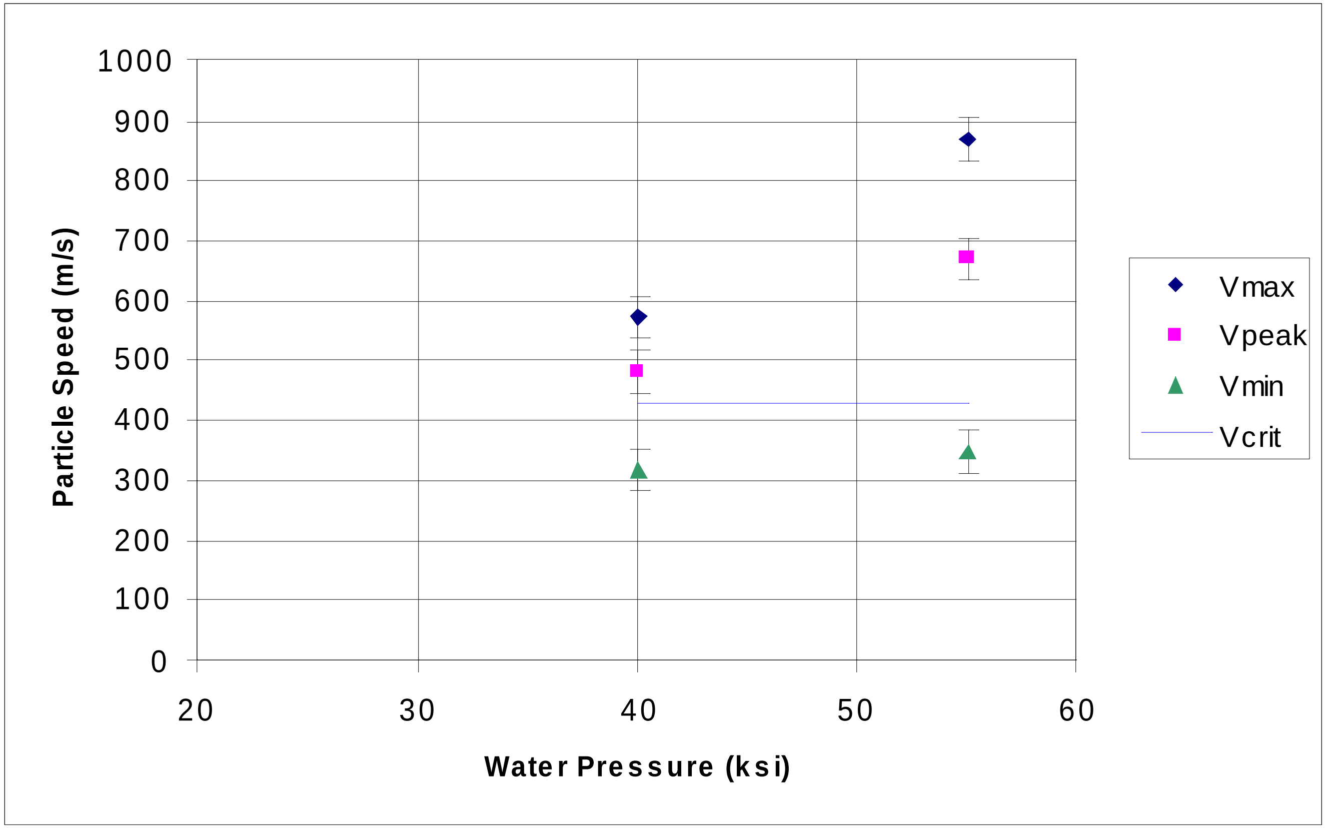
Velocity versus Jet Pressure



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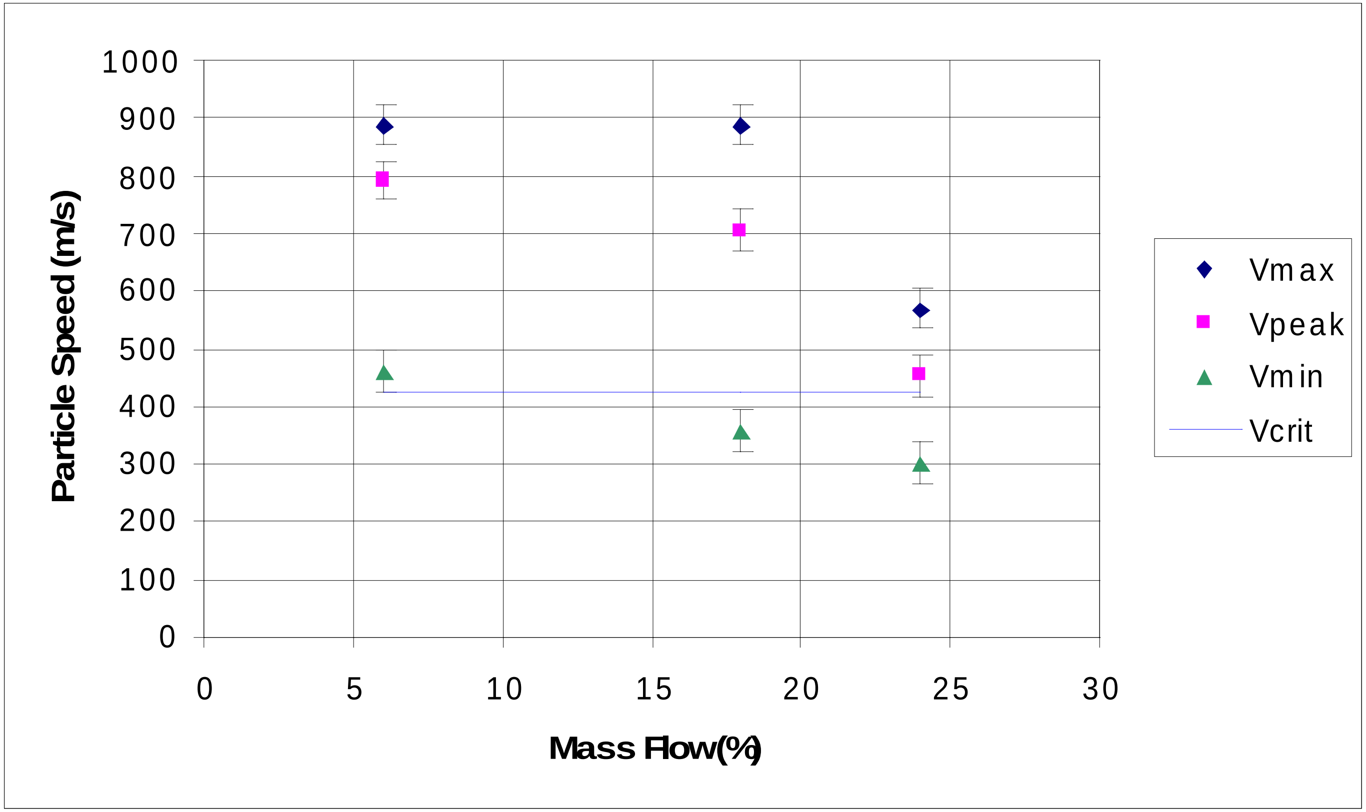
Potential for high deposition rate



18% mass flow of powder means 1.5 lbs per minute!

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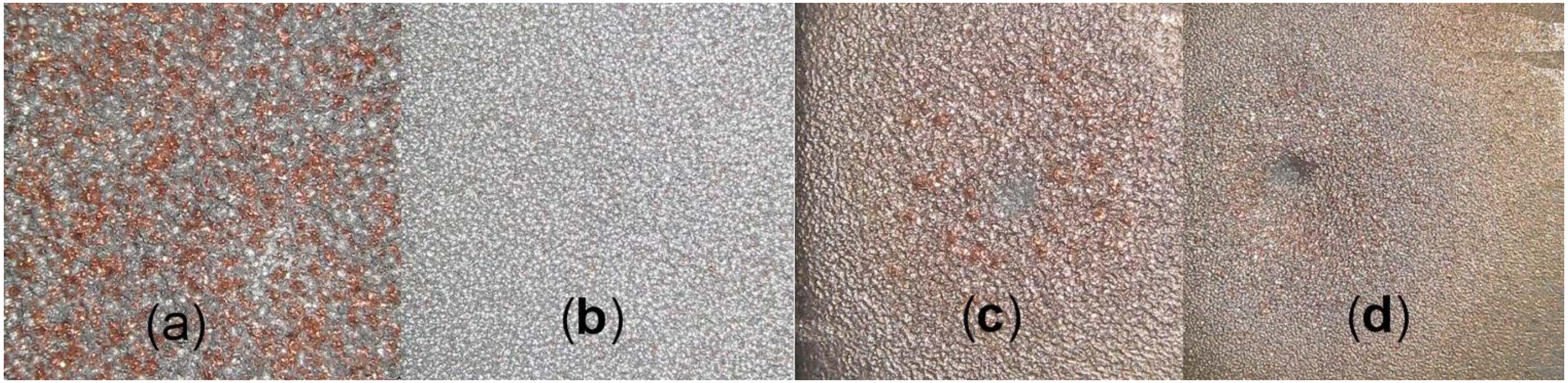
Coupon testing poor deposition



a) Al- large particles, b) Al-small particles, c) Steel-large particles, d) Steel-small particles - all copper particles

Water is problem fluid

- Water is simple, cheap and safe working fluid.....
- ...but it interferes with the coating deposition
- Even a 0.0001" layer of water around a particle is enough to absorb the impact energy as it flashes to steam
- Attempts to draw off the water were 99%+ successful - but not good enough

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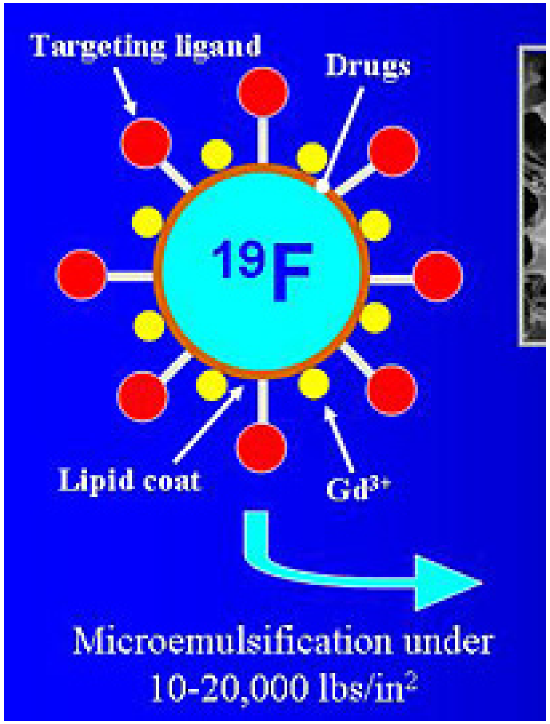
Alternate Fluid

- Perfluorocarbons have very low latent heat of vaporization – easily flash to gas after exiting nozzle without cooling particle/substrate interface
- High volume gas high speed could be used to further accelerate the particles
- Perfluorocarbon used as a nanoparticle carrier for MRI - might be useful for nano powder coatings



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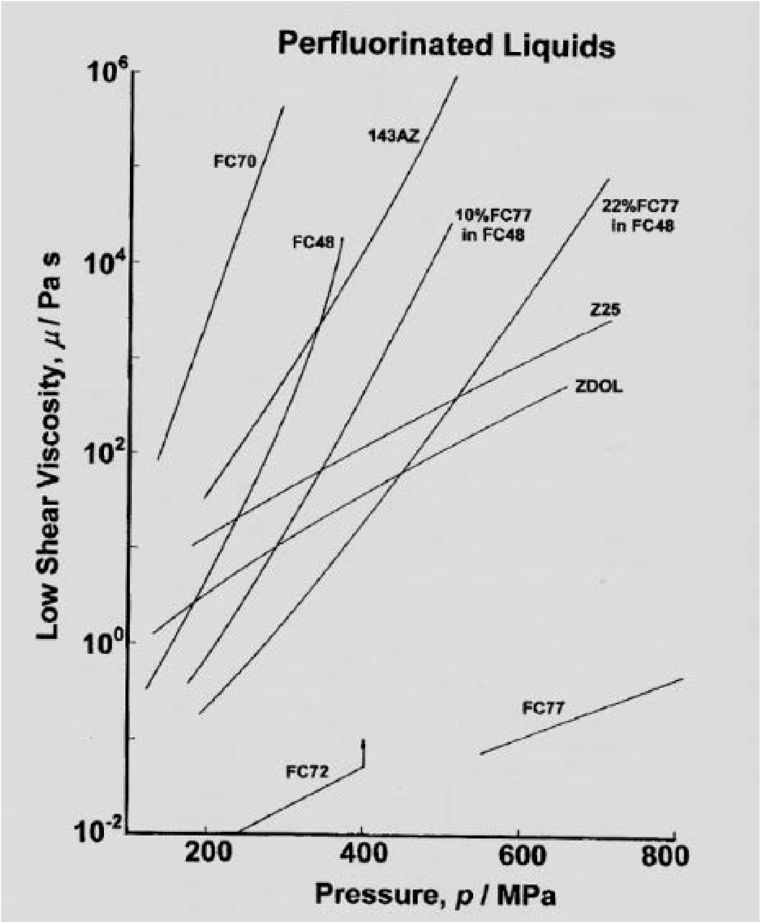
Which Perfluorocarbon?



- In Phase I, fluorocarbon turned "solid" at 40ksi (280 MPa)
- Need to choose low viscosity, high pressure version like FC77
- Need higher pressures to get to higher particle velocity because of higher fluid density

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Phase II Objectives

- Develop the liquid accelerated cold spray process and show that the method can make thick metallic coatings that have the potential to be built up into liners and solid parts.

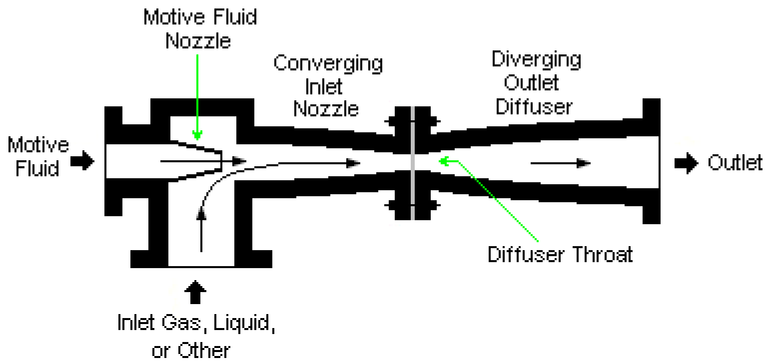
Work Plan

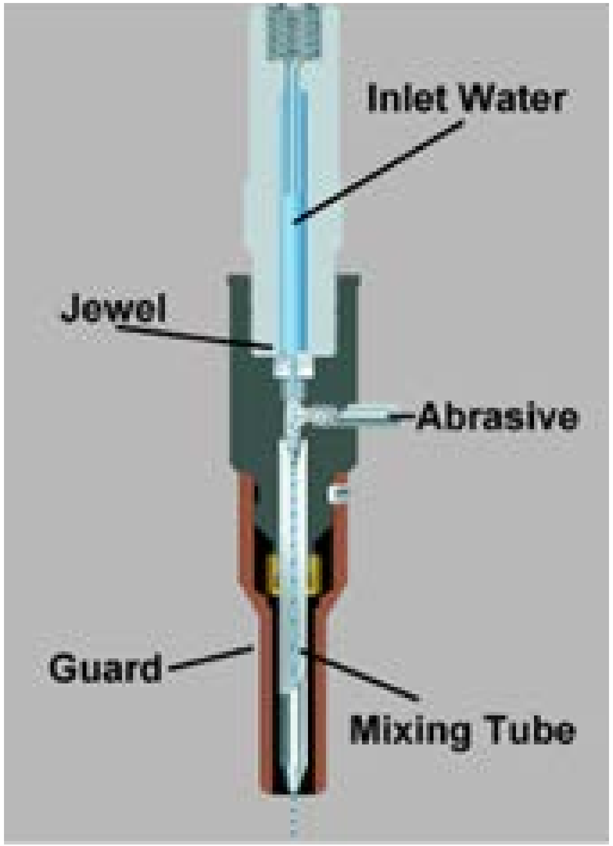
- Task 1. Determine candidate fluids and dual phase nozzle design.
- Task 2. Modify pumping equipment for perfluorocarbons at high pressure.
- Task 3. Coat with new fluids and nozzles.
- Task 4. Build fluid recovery system.
- Task 5. Test spraying of pre-mixed ultra-fine particles.
- Task 6. Characterize the metallurgical properties of the deposited material.
- Task 7. Coat first application part.
- Task 8. Design of Prototype Liquid Cold Spray Work Station.
- Task 9. Reports

Liquid and gas acceleration

Two-stage acceleration of particles – high velocity liquid then high velocity gas as the liquid flashes to gas and accelerates in the diffusion section.

Two stage particle acceleration has been done before for surface preparation





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Premixed Slurry with Isolator

- An alternate approach is to premix the powders with the liquid and accelerate them through the nozzle.
- Results in very high particle velocities (almost same as the fluid).
- Might be very applicable to nano powders.
- Ormond has extensive experience with pre-mixed slurry systems.

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90,000 psi Test Setup

Recent Progress

- Direct pumping of perfluorocarbons at 90,000 psi.
- Modified an isolator to run perfluorocarbons at 90,000 psi so premixed powders can be run.
- Fluid velocity at 1,000 m/s
- Jet turning to vapor in about 6 inches
- Will be running copper powers accelerated by perfluorocarbons over the next few weeks as we look to improve deposition efficiency and adhesion.